Yield and Forage Quality of Six Teff Seed Brands as Affected by Seeding Date in the Klamath Basin, 2009

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Introduction

There are times when forage producers desire a quick-growing, high quality annual forage in mid-summer in situations such as: less-than full season irrigation water supply; need for an emergency crop due to crop failure; or forage rotation crop between alfalfa stands. Currently there are few good options in these situations. Teff is a warm-season annual grass that can produce good quality forage during a short, summer time frame, and thus has the potential to be a viable alternative in such situations. Starting in 2003, we have grown teff in quasi-commercial fields and then in small plot research trials at the Klamath Basin Research & Extension Center (KBREC). As we study various

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management options, it has become clear that ongoing research is needed to understand the optimum crop production requirements for this new crop.

Teff (*Eragrostis tef* [Zucc.], *Poaceae)* is a C_4 annual tropical grass. Teff is traditionally harvested for grain in Ethiopia, where it was first domesticated between 4000–1000 BC. Teff flour is preferred in the production of injera, a major food staple in Ethiopia. Teff is grown on a limited basis for livestock forage in other parts of Africa, India, Australia and South America. In the US, small acreages of teff are grown for grain production and sold to Ethiopian restaurants throughout the country. Teff grain is sold in some grocery stores as well. Since the popular press article describing our early efforts was published (Zenk, 2005), many growers, hay buyers, seed companies, and research/extension faculty at other universities have begun studying, growing, or buying this new crop. A recent follow-up article has documented increased national interest in this crop (Zenk, 2008). While our interest in teff has been primarily as a forage, teff's traditional use in food has also received renewed interest due to its very low levels of gluten. Approximately 1 million Americans suffer from Celiac disease (gluten sensitivity) and teff may provide a niche for meeting these dietary requirements as a gluten-free food source.

For a more detailed discussion about teff's history, characteristics, and uses, as well as our early experiences and experiments with this new crop, please refer to our 2005 annual report (Roseberg et al., 2006).

Objectives

Much of the teff available in commerce is common landraces, not released varieties, and thus have varying degrees of uniformity and unknown performance. Because several seed brands have been marketed in recent years, we realized that a controlled comparison of these commercial seed types was necessary to better understand the genetic diversity and to better advise growers on seed choices. While it has been established that teff is not tolerant to killing frosts at any growth stage, the effects of cool soil and air temperatures during germination and seedling growth is not well understood. We began testing the effect of seeding date on commercially available teff brands in 2007 (Roseberg et al., 2007 and 2008). To further confirm the earlier results and to examine differences in year-to year results due to varying annual weather patterns, we have continued testing teff. The objective of this study was to evaluate six seed seeded on three dates in the spring to evaluate how growth, yield, and quality are affected by date of seeding and thus early (and late) season weather.

Procedures

The trial was planted at the KBREC research farm on a Poe fine sandy loam soil. The previous crop was potatoes in 2008. The teff seed brands tested in this experiment were 'Dessie' and 'Pharaoh' from First Line Seeds (Moses Lake, WA), 'VAT-1' from Hankins Seed (Bonanza, OR), 'Tiffany' from Target Seeds (Parma, ID), and 'Emerald'

from Green Valley Seed (Kahoka, MO), and 'Excalibur' from United Seed Services (Caldwell, ID). The experiment was laid out as a randomized complete block with four replications of each seed type within each of three seeding date blocks. Teff was seeded at about ¼ inch depth at a seeding rate of 6 lb/ac with a Kincaid (Kincaid Equipment Mfg) research seed drill with a small-seed cone attachment on May 29, June 11, and June 25, 2009. The plots were 20.0 by 4.5 ft, (9 rows at 6-inch spacing), with a harvested area of 14.0 by 3.0 ft. All plots were fertilized with 55 lb/ac N, 16 lb/ac P_2O_5, no K_2O, and 60 lb/ac S banded at seeding (applying a custom blend of 19.7-5.6-0-21.5 fertilizer at 280 lb/ac). A tank mix of fluroxypyr (Starane®) herbicide was applied at 1.0 pint/ac (0.19 lb a.i./ac) with a commercial mixture of 2,4-D and dicamba (Weedmaster®) herbicide applied at 3.0 pint/ac (0.38 lb a.i./ac of dicamba plus 1.08 lb a.i./ac of 2,4-D) on July 16. No crop injury was apparent at any time after spraying. Within a few days after the first harvest of each seeding date block, ammonium sulfate was applied at 255 lb/ac (supplying 54 lb/ac N and 61 lb/ac S).

Cutting date was chosen based on overall physiological maturity of the six seed types for a given seeding date. Thus for each seeding date, the plots were cut when seedheads were just beginning to emerge. Using this criterion, the May 29 seeding date block was cut on August 4 and again on September 9. The June 11 seeding date block was cut on August 4 and again on September 9. The June 25 seeding date block was cut on August 13 and again on September 9. Teff in the June 25 seeding date block was not quite as mature by September 9 as the earlier seeding dates, but very cool temperatures in early September (including a low temperature of 33.6^o F on September 7) effectively ended the plant growth without killing the plants outright.

Precipitation and other weather data were measured by the US Bureau of Reclamation Agricultural Meteorological (AgriMet) automated weather station at KBREC (US Bureau of Reclamation, 2009). Rainfall amounts totaled 1.84 inch in June, 0.17 inch in July, 0.20 inch in August, and none in September before the second harvest date. Irrigation was applied with solid-set handlines. The May 29 seeding date block received 9.29 inches of irrigation applied on 9 dates between seeding and first cutting, plus another 3.72 inches of irrigation applied on 4 dates between first cutting and second cutting. The June 11 seeding date block received 8.00 inches of irrigation applied on 8 dates between seeding and first cutting, plus another 3.72 inches of irrigation applied on 4 dates between first cutting and second cutting. The June 25 seeding date block received 8.44 inches of irrigation applied on 9 dates between seeding and first cutting, plus another 2.29 inches of irrigation applied on 2 dates between first cutting and second cutting.

Forage fresh weights were measured immediately in the field and samples were collected from each plot for drying to correct yields to a dry weight basis as well as perform forage quality analysis. After drying and weighing, samples were ground to 2-mm-sieve size in a Wiley Mill (Arthur H. Thomas Co.) and to 1-mm-sieve size in an Udy Mill (UDY Corporation) before being analyzed in a near infrared spectrophotometer (NIRS) (NIRSystems, FOSS, NA, Minneapolis, MN) to determine forage quality. Quality testing at KBREC was accomplished using the NIRS and equations developed by the NIRS Consortium, Madison, WI (NIRS Consortium, 2007). We used NIRS equations developed for other grasses due to the limited data available for teff. Reported forage

quality parameters included crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV), and relative forage quality (RFQ).

Statistical Analysis

Statistics on yield and quality data were calculated using SAS® for Windows, Release 9.1 (SAS Institute, Inc.) software. Treatment significance was based on the F test at the $P = 0.05$ level. If this analysis indicated significant treatment effects, least significant difference (LSD) values were calculated based on the student's *t* test at the 5 % level. For this report, the experiment was analyzed as a split-block-in-time design, with seeding date as the main plot and seed brand as sub-plot.

Results and Discussion

Yield Results

Observed differences in yield between seeding dates were statistically significant for first cutting, second cutting, and annual total yield (Table 1). First cutting yields for all seed brands were highest for the June 25 seeding date, whereas the May 29 seeding date had the lowest yields at first cutting. At second cutting, the yields for all seed brands were highest for the June 11 seeding date, and yields from the May 29 seeding date were again the lowest of the three dates. Thus it is not surprising that the annual yield total for the May 29 seeding date was far lower than for the other two dates. The annual yield total from the June 11 seeding date was higher than from the June 25 seeding date, although differences for a given seed brand between the two dates was not significant. Overall, yields were slightly lower for the second cutting than for the first.

Looking at seasonal yield patterns for a given seeding date, all of the May 29 entries (except Dessie) tended to have higher yields at first cutting. All June 11 entries had higher yields at second cutting. Conversely, all June 25 entries had a higher first cutting yield. The seasonal yield pattern reflects teff's slower and poorer overall growth during the cool springtime, despite the longer time period between seeding and first cutting compared to the other seeding dates (Fig. 1). The shortened growing season probably reduced the potential of the second cutting yield for the June 25 seeding date (Fig. 2 and 3). In this climate the potentially cold temperature in both the late spring and late summer can limit the productive growing season for teff.

Differences in yield between teff seed brands were not statistically significant for first cutting, second cutting, or annual total yield. The seeding date by seed brand interaction was not significant for first cutting, second cutting, or annual total yield. This lack of interaction indicates that the non-significant yield response of the seed brands was consistent for all the seeding dates.

Quality Results

Differences in between seeding dates were statistically significant for all measured quality parameters except second cutting RFQ (Tables 2 and 3). At first cutting, the June 25 seeding date had higher crude protein and lower ADF than the other two dates. The May 29 seeding date tended to have the highest ADF, but the lowest NDF. Because RFV is calculated using ADF and NDF values, the RFV values did not follow a consistent pattern between seeding dates at first cutting.

At second cutting, crude protein was highest for the June 25 seeding date and lowest for the Jun11 seeding date. ADF and NDF were lowest for the June 25 seeding date, resulting in the overall highest RFV values at second cutting. In 2009, the ADF and NDF data clearly showed that the shorter the time period between first and second cutting, the lower the fiber content, resulting in higher RFV (Table 3). Thus, the good quality, but lower yield, for the June 25 seeding date at second cutting lends credence to the idea that near-freezing temperatures in early September caused the teff to stop growing and maturing sooner than it would have otherwise.

Differences between seed brands were only significant for crude protein on both cutting dates, NDF on the second cutting date, and RFQ on the second cutting date (Tables 2 and 3). The seeding date by seed brand interaction was not significant for every quality parameter. This indicates that seed brands responded the same relative to each other for the various seeding dates. Dessie tended to have high protein for all seeding date by cutting dates combinations- other brands had varying levels of protein and none were consistently high or low for all seeding date by cutting date combinations. Pharaoh tended to have higher RFV values under most, but not all, seeding date by cutting date combinations. Other brands had a less consistent response relative to each other. Dessie usually had the lowest RFQ, while the other brands had a more variable response relative to each other.

Mean RFV was low compared to previous years (all under 116), thus making it harder to detect outstanding combinations of seeding date and seed brand in 2009. RFQ was also relatively low (none over 109). The difference in the way RFV and RFQ are calculated may explain some of the reason why the overall statistical significance, as well as responses of individual seed brands to different seeding dates, may not be the same for RFV and RFQ. Whereas RFV is a relatively simple calculation derived from ADF and NDF, RFQ is a more complicated calculation derived from non-fibrous carbohydrate, crude protein, fatty acids, nitrogen-free NDF, 48-hour *in vitro* digestibility, and NDF (Undersander and Moore, 2002). Thus, the RFQ calculation attempts to estimate animal intake more accurately than RFV by including additional important nutritive qualities in the equation.

Conclusion

Teff grew well and produced moderate, but not outstanding, yields and quality for all seed brands compared to previous years. The best overall combination of yield and quality seemed to result from the mid-June seeding, but if production goals included

higher first cutting or second cutting crude protein, RFV, or other quality parameter, then adjusting the seeding date could result in higher quality at a potential decrease in yield at either the first or second cutting. This type of study should be repeated in future years with additional seed brands at additional locations to better determine the best window to maximize seasonal yield and quality while trying to avoid growth reduction or frost damage due to cool weather both in the spring and early fall for a given production location.

References

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Table 1. 2009 Yield summary for the teff seed brand by seeding date trial.
Klamath Basin Research & Extension Center, Klamath Falls, OR.

		Yield (lb/ac) O.D.					
Seed Brand	Seeding Date	Cut 1	Rank	Cut 2	Rank	Total Yield	Rank
VAT-1	May 29	1950	16	1842	17	3791	15
Dessie	May 29	1640	18	2010	13	3649	18
Emerald	May 29	2046	15	1698	18	3743	17
Excalibur	May 29	2130	14	1973	14	4103	14
Pharaoh	May 29	1907	17	1853	15	3760	16
Tiffany	May 29	2335	13	1846	16	4180	13
VAT-1	June 11	3263	9	3962	5	7225	3
Dessie	June 11	2844	10	3829	6	6672	9
Emerald	June 11	3437	5	4009	4	7446	2
Excalibur	June 11	3396	6	4080	3	7475	1
Pharaoh	June 11	2523	12	4322	1	6844	6
Tiffany	June 11	2661	11	4179	2	6840	7
VAT-1	June 25	3710	4	2734	10	6444	10
Dessie	June 25	3346	8	2732	11	6077	12
Emerald	June 25	4249	1	2934	9	7184	4
Excalibur	June 25	4015	3	2941	8	6956	5
Pharaoh	June 25	3352	7	3083	7	6434	11
Tiffany	June 25	4243	2	2590	12	6833	8
Mean		2947		2923		5870	
***P* (Seeding Date)**		**0.002**		**<0.001**		**<0.001**	
LSD (0.05)- Seeding Date		679		489		997	
***P* (Seed Brand)**		**0.210**		**0.849**		**0.313**	
LSD (0.05)- Seed Brand		NSD		NSD		NSD	
CV (%)		27.9		19.0		15.9	
***P* (Seeding Date X Seed Brand Interaction)**		**0.916**		**0.970**		**0.976**	

Table 2. 2009 Crude protein, acid detergent fiber, and neutral detergent fiber summary for the teff seed brand x seeding date trial. Klamath Basin Research & Extension Center, Klamath Falls, OR.

		Crude Protein (%)				ADF				NDF			
Seed Brand	Seeding Date	Cut 1	Rank	Cut 2	Rank	Cut 1	Rank	Cut 2	Rank	Cut 1	Rank	Cut 2	Rank
VAT-1	May 29	14.6	12	15.5	12	39.0	1	36.7	8	48.9	16	52.0	9
Dessie	May 29	15.4	9	17.0	4	37.1	7	36.2	12	49.4	15	52.8	7
Emerald	May 29	13.4	15	16.2	7	38.6	2	36.0	13	51.7	14	50.7	13
Excalibur	May 29	13.1	17	16.1	8	38.0	5	36.4	10	52.6	11	51.8	11
Pharaoh	May 29	15.0	11	15.6	9	38.5	3	37.0	6	48.2	17	52.6	8
Tiffany	May 29	15.1	10	15.6	10	38.5	3	37.0	6	47.5	18	51.9	10
VAT-1	June 11	14.0	14	14.4	15	36.2	10	37.4	4	56.1	2	54.8	2
Dessie	June 11	14.5	13	14.9	13	36.6	9	37.4	4	55.6	3	54.3	5
Emerald	June 11	13.3	16	13.9	17	37.1	7	37.8	1	55.1	4	53.0	6
Excalibur	June 11	12.0	18	13.8	18	37.6	6	37.7	2	58.4	1	54.5	4
Pharaoh	June 11	15.8	7	13.9	16	34.8	14	37.7	2	53.2	10	55.0	1
Tiffany	June 11	15.7	8	14.4	14	34.2	16	36.7	8	53.3	9	54.6	3
VAT-1	June 25	17.8	2	16.7	5	34.6	15	35.3	15	53.7	7	50.5	14
Dessie	June 25	19.8	1	18.2	1	33.4	18	34.9	18	51.9	13	49.8	15
Emerald	June 25	16.2	4	16.5	6	35.1	12	35.4	14	53.4	8	49.6	17
Excalibur	June 25	15.8	6	17.1	3	35.6	11	35.1	16	54.2	6	49.0	18
Pharaoh	June 25	17.7	3	15.6	11	34.1	17	36.4	10	52.6	11	51.1	12
Tiffany	June 25	16.1	5	17.6	2	35.1	12	35.0	17	54.4	5	49.7	16
Mean		15.3		15.7		36.3		36.4		52.8		52.1	
***P* (Seeding Date)**		**<0.001**		**<0.001**		**0.001**		**<0.001**		**0.003**		**<0.001**	
LSD (0.05)- Seeding Date		0.8		0.7		1.2		0.4		2.2		1.1	
***P* (Seed Brand)**		**<0.001**		**0.032**		**0.178**		**0.092**		**0.151**		**0.048**	
LSD (0.05)- Seed Brand		1.4		0.9		NSD		NSD		NSD		1.1	
CV (%)		10.7		7.3		4.6		2.0		6.7		2.6	
***P* (Seeding Date X Seed Brand Interaction)**		**0.386**		**0.771**		**0.257**		**0.303**		**0.861**		**0.886**	

Table 3. 2009 Relative feed value and relative forage quality summary for the teff seed brand x seeding date trial. Klamath Basin Research & Extension Center, Klamath Falls, OR.

		RFV				RFQ			
Seed Brand	Seeding Date	Cut 1	Rank	Cut 2	Rank	Cut 1	Rank	Cut 2	Rank
VAT-1	May 29	112	5	108	9	98	16	98	9
Dessie	May 29	114	3	107	11	100	11	88	18
Emerald	May 29	106	11	112	6	100	10	97	10
Excalibur	May 29	106	12	109	8	102	7	95	14
Pharaoh	May 29	115	2	106	12	99	14	96	13
Tiffany	May 29	116	1	108	10	100	12	95	15
VAT-1	June 11	101	17	102	17	103	6	99	6
Dessie	June 11	101	16	103	15	100	13	94	16
Emerald	June 11	102	15	104	13	103	4	97	10
Excalibur	June 11	95	18	102	16	101	8	99	5
Pharaoh	June 11	108	8	101	18	107	2	100	2
Tiffany	June 11	109	7	103	14	109	1	101	1
VAT-1	June 25	107	10	113	5	100	9	100	3
Dessie	June 25	113	4	115	3	93	18	94	17
Emerald	June 25	107	9	115	4	98	15	99	7
Excalibur	June 25	105	14	117	1	103	5	98	8
Pharaoh	June 25	110	6	110	7	96	17	99	4
Tiffany	June 25	106	12	115	2	104	3	97	12
Mean		107		108		101		97	
***P* (Seeding Date)**		**0.021**		**<0.001**		**0.048**		**0.069**	
LSD (0.05)- Seeding Date		5		3		4		NSD	
***P* (Seed Brand)**		**0.102**		**0.051**		**0.079**		**<0.001**	
LSD (0.05)- Seed Brand		NSD		NSD		NSD		2	
CV (%)		7.9		3.2		5.0		3.3	
***P* (Seeding Date X Seed Brand Interaction)**		**0.855**		**0.825**		**0.188**		**0.539**	

Fig. 1.Teff First Cutting Yield at the Klamath Basin Research & Extension Center, 2009

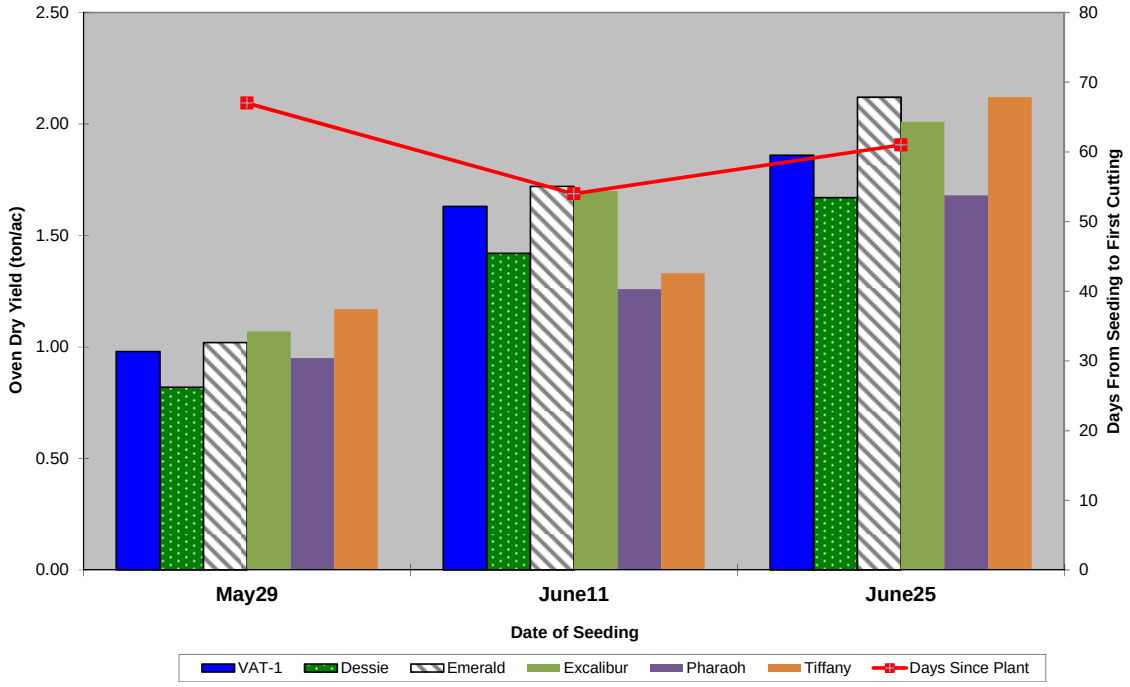

Fig. 2.Teff Second Cutting Yield at the Klamath Basin Research & Extension Center, 2009

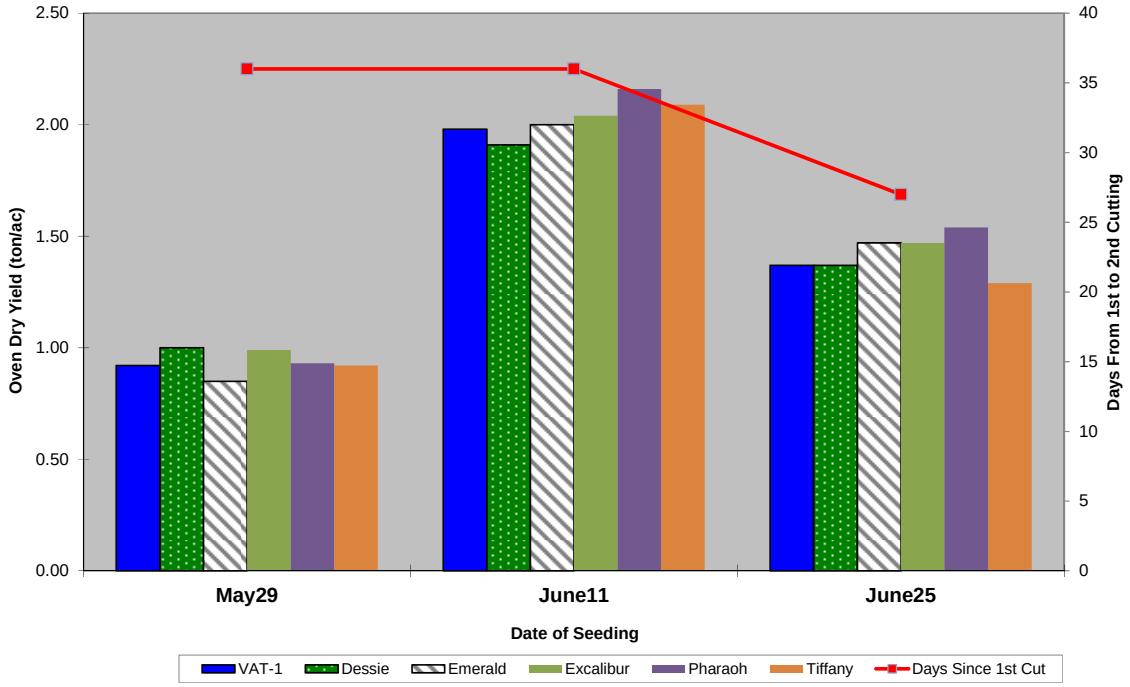

Fig. 3.Teff Season Total Yield at the Klamath Basin Research & Extension Center, 2009